Thermal Exposure of Ammunition On Board Ship
Part 3. Ammunition Ships

by
Howard C. Schafer
and
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JUNE 1981

NAVAL WEAPONS CENTER
CHINA LAKE, CALIFORNIA 93555
FOREWORD

This report presents results of an investigation to determine the valid shipboard thermal environment of ammunition. The work was conducted by the Naval Weapons Center (NWC), China Lake, California, and supported by the Naval Air Systems Command under AirTask A03W-3300/008B/F31300000.

This report, Part 3, covers the probable thermal exposure to be found on cargo type ships. The previously published volumes, Part 1 and Part 2, cover cruisers/large destroyers and aircraft carriers, respectively.

This report has been reviewed for technical accuracy by J. P. Jones.

Approved by
R. V. BOYD, Head
Range Department
15 June 1981

Under authority of
W. B. HAFF
Capt., U.S. Navy
Commander

Released for publication by
R. M. HILLYER
Technical Director
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(U) The magazine air temperature records from general cargo and logistic support type ships have been statistically analyzed to obtain the probable thermal exposure to be found on these type ships. The information is divided into the temperature expectancies for the various deck levels as applicable. Effort has been made to eliminate information from compartments influenced by the engine room. This report includes more than 400,000 data points from 24 ships. The ships were assigned to the 1st, 2nd, 6th and 7th Fleets in the time frame of 1958 through 1973.
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Table 1: Data Ships

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2
INTRODUCTION

An important factor in designing a ship-launched weapon is the environmental temperature range the weapon will experience during storage and transportation. As part of a larger program aimed at determining the stockpile-to-target environments that will be experienced by air-launched weapons, a study was undertaken to define the thermal regime as it pertains to shipboard storage.

Recording of the maximum and minimum air temperatures in each magazine on board every ship in all fleets has been required for years. This requirement, however, was strictly for safety; the records were usually retained on board the ship for only 1 to 2 years and then destroyed. At the request of the Naval Weapons Center (NWC), the Chief of Naval Operations in 1967 instructed all Fleet elements to send their obsolete magazine records to NWC for use in this project. Ships from all numbered fleets, including the 6th and 7th Fleets, responded to this request; the information from frigates and aircraft carriers was reported in Parts 1 and 2 of this report series.

This volume, Part 3, presents the data and results as they pertain to cargo and logistic type ships. Eventually all ship classes may be divided into logical study units and similar reports detailing the storage temperatures for each group prepared and published as the need is expressed.

More than 400,000 maximum or minimum temperature data points collected from all types of compartments and lockers on all levels of cargo ships have been integrated into this report. (This represents over 200,000 ship magazine days of measurement.) The data collection time frame for each ship ranged from a few months to years. Many of these ships are no longer in service; however, the data are considered valid since all ammunition compartment temperatures tend to describe a very narrow band of exposure. Also, it was thought these obsolete ships data would detail any thermal differences that would exist in future supply ship design, if such tend to exist.

A complete definition of the extreme temperature circumstances is not provided since the exact day-by-day position of the ship is not known. Therefore, it is possible that in spite of the mass of data presented a chance of exposure to less moderate temperatures could be experienced. Also, there was no control over ship deployment or of the personnel actually recording the individual temperature readings. The sources of error in the existing collection system, however, have been investigated and compensation was made. For example, the measuring instrument, a "horseshoe" thermometer equipped with maximum and minimum temperature tattletales, could be affected by ship vibration. If mounted on a resonating bulkhead, the vibration could shake the tattletales down to the
meniscii of the mercury. This is evidenced in the records by identical maximum and minimum temperature entries for an interval of several days.

The lack of ship location information for a given day does not invalidate the data obtained since a correlation was made during the investigation on the service temperature of the antisubmarine rocket (ASROC) missile.\textsuperscript{1,2} In this correlation, the recorded sea water temperature was compared with the minimum recorded ASROC motor temperature for the same day. The resulting readings were within a few degrees of each other. Since the data were from ships\textsuperscript{1,2} assigned to the 7th Fleet, and this Fleet's area of interest is the Western Pacific, given the month and minimum compartment temperatures, a good guess can be made as to where the ship was located. As indicated in footnotes 1 and 2, the Western Pacific could be the warmest area in which our ships will be required to be deployed. When considering the cold-extreme situations, there is a logically self-limiting factor. For instance none of the ships providing data were in the Beaufort Sea during winter. This sea is ice choked in winter and a ship would quite possibly be stuck in the ice until the next summer.

During the data accrual period, the candidate ships were deployed between 9° and 20° north latitude in the South China Sea. Thus these data, though incomplete and imperfect, are of extreme value in determining the environmental temperature criteria to which a majority of ship-launched ordnance will be exposed. This work then lays a foundation for determining the ammunition ship's maximum and minimum temperature regime for any nonheat generating naval material so as to be in design compliance with DOD Directive series 4120 and 5000. In addition, these data are indicative of the "ship transported" thermal regime of all ordnance and military material.

As stated above, the data presented herein do not permit the exact correlation of ship location at the time a given temperature was recorded. However, these data indicate that ships herein included were underway in the North Atlantic during January, and in the West Pacific during the tropical hot season. These ships operate both independently and within an aircraft carrier task force. Therefore, it is safe to assume that more severe ammunition exposure during this event of the factory-to-target sequence will be nonexistent to rare. Based on these considerations it


can be stated that the probable chance of occurrence of the ordnance and material response temperature is as herein displayed.

INSTRUMENTATION

The horseshoe-type mercury thermometer (Figure 1) was used to obtain the data. This type thermometer, equipped with a floating steel tattle-tale device, allows maximum and minimum temperatures to be recorded. The tattle-tale device rests on the menisci of the mercury and moves only in the upward direction. When a meniscus moves in the downward direction it leaves the tattle-tale at the departure point, thus indicating the maximum or minimum temperature for the measurement period. Using a magnet, the tattle-tales are reset to rest on the menisci after recording the maximum and minimum temperatures. These thermometers are generally mounted on the bulkhead of the ship or laid on top of the ordnance within the locker.

The thermometer manufacturers (Taylor, Weksler and Moeller) warrant that the temperature readings are accurate to within 2°F at the time of delivery.

DATA HANDLING

The raw data were received from the many ships in various forms, i.e., temperature logbooks, individual monthly magazine temperature record cards or individual temperature record sheets gathered together in an envelope. These records identified the month, day and year the temperatures were recorded as well as the magazine or compartment of data origin.

These raw data were keypunched, reduced, tabulated and plotted to yield meaningful statistics and significant points of interest for upper and lower deck levels of various ships types and groups of similar ships. (Appendix A details the processing of the raw data.) The upper deck level was defined as the second deck and above; the lower deck level was the third deck and below. This division of levels took into account the temperature data from above and below the waterline and their possible effects. Appendix B provides an explanation of the deck level and compartment identifications.
RESULTS AND CONCLUSIONS

During this investigation, 411,949 data points were collected on the ships covered in this report. These data represent a composite of the 15 years from 1958 through 1973. The types of ships providing these data can be arbitrarily divided into two groups according to hull design and characteristics: medium to large cargo type ships, and special purpose ships. The few small or special purpose ships data are included to indicate the similarity of thermal response of the whole. The following discussions of the specific ship classes and the "logistic" fleet in general bear out that the thermal environment aboard such craft is truly moderate.

Though the data presented herein make it highly obvious, it must be stated that the old design values of -65° and 160°F were never experienced. Temperatures of these magnitudes simply are not in evidence on-board any logistic ship. This fact was previously recognized in Parts 1 and 2 of this report series as related to cruisers, guided missile frigates, and aircraft carriers.

CLASSIFICATION

The grouping of ships for publication in this report is somewhat arbitrary. A quick look at the picture of each candidate ship will show that they all appear, to the uninformed layman, to be cargo ships, with the exception of a small mine sweeper, an amphibious transport dock ship, and a very special purpose ship converted from an old antisubmarine warfare (ASW) "Jeep" carrier. These last three ships were included partially because they do not conform to any other part of this report series, and their data indicate that the magazine temperature is more a function of the temperature of the sea than the size of the ship. Therefore, all the ships herein reported will be viewed as one ship class. However, to a true sailor this is blasphemy. So, in general, the major classifications of ships consist of ammunition ships, destroyer tenders, repair ships, submarine tenders, and the three aforementioned miscellaneous ships; the CC-2, LPD-2 and MSC-198. To be more specific in the identification of the candidate ships, Table 1 is presented.

LOGISTIC SHIP FLEET

The ships that provided magazine temperature data are listed in Table 1. Figures 2 through 25 indicate the differences in structure and size of these representative U.S. Navy cargo duty ships both past and present.
### TABLE 1. Data Ships.

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<td>AD-23</td>
<td>1966-1968</td>
<td>10</td>
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<td>U.S.S. Frontier</td>
<td>AD-25</td>
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<td>AD-29</td>
<td>1962-1966</td>
<td>14</td>
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<tr>
<td>U.S.S. Tidewater</td>
<td>AD-31</td>
<td>1965-1968</td>
<td>15</td>
</tr>
<tr>
<td>U.S.S. Ajax</td>
<td>AR-6</td>
<td>1958-1966</td>
<td>17</td>
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<td>U.S.S. Wright</td>
<td>CC-2</td>
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An attempt was made to consolidate all the data from these ships. Since the data were so similar, it was thought that the data from these ships might conveniently group to provide a truly universal display of magazine temperature data for any given level in a cargo ship operating in U.S. Navy Fleets or oceans of the world. Note that at no time during the 15 calendar years of this data accumulation effort was any ship tasked to sail to a given area specifically for this project. Rather, it can be assumed that sailing orders for any ship were typical of that particular fleet's mission during that period. Therefore, it seems logical that a random use population of mission induced magazine temperature information was indeed derived.

Since the data are so similar it was decided by the authors to present a detailed display of level-by-level results for only one ship type. Also, since the title for this report is Ammunition Ships, the AE seemed the logical ship type for a detailed display.

Figures 26-29 are the displays of data from a composite of the above the main deck levels of all the reporting AE type ships. Notice that their temperature extreme end points are all about the same. Also, that there is a difference in curve shape and mean point. This can be explained by the fact that these upper deck lockers are of the same type and construction as shown in Figure 1. Also, the thermometer is not located in a fixed position, but depends on the locker load for position with respect to the top and sides of the metal lockers.

In comparison, the data display of Figures 30-35 are all much more regimented. Notice that the below decks holds of ammunition ships are much more moderated. This is because the below deck temperature regime is forced by the temperature of the ocean water in which the hull floats. It is of interest to note in Figures 26-29 that a lower locker temperature of 18°F was experienced during small portions of a three day span on one ammunition ship on the North Atlantic run during winter. Also, notice in Figures 30-35 that this same low temperature value does not show up at all. The ocean is one big heat sink. The ocean also turns solid at 27°F. Therefore, a ship afloat, being thermally (and physically) small, will at the most extreme only follow the thermal regime of the water in which it floats. However, the air above the water is the thermal matrix in which the ready-service, or above deck pyrotechnic lockers are immersed. It is very believable that these lockers would experience lower temperatures than the holds of the ship. It is interesting that the reported temperature low of 18°F was only experienced by one ship in the period of record since many ships in this sample traveled the same sea lanes. The conclusion can be made that even in the North Atlantic in winter the chance of these extreme temperatures being experienced by the cargo is exceedingly small.
Figures 36 and 37 are the statistical sum of Figures 26-29 and 30-35. Figure 38 is the complete data display for all compartments of the AE ships reporting from all numbered fleets. Here it is very evident that the thermal regime of the ammunition ship is indeed benign.

Figures 39-44 indicate that all cargo ships can be grouped into a common category and that they respond the same thermally as the AE type ammunition ship. During the preparation of this report, these figures were all placed on a light table; very few differences were apparent. Figure 44 is in reality the bottom line on the thermal response of cargo during ship transportation. Notice that its end points are very divergent when compared with individual figures. Also notice the shallow slope of the asymptotic approach to these end points. All this indicates is that there were not very many data points out of the 411,949 reported herein. This figure really indicates that about 80% of all these data are grouped between 55° and 85°F.

Figure 44 provides a total accumulation of all ships composite data. This figure can be used, for all intents and purposes, as the thermal criterion for storage of ordnance munitions and material on board ships.

In Figure 44 the curve shape is very symmetrical. The symmetry is very similar to that of a Gaussian distribution. Because a Gaussian display more easily portrays the "extreme" or end point data, while fully portraying the central portion of the data population, an attempt was made to place Figure 44 in Gaussian format. Figure 45 is a replot of Figure 44 data on Gaussian paper. The prime use of Figure 45 is to derive a quantification for even more "extreme" data than were measured during this project. Because there is no end point to a Gaussian distribution, the straight line of Figure 45 can be extended out to infinity if desired. By the statistical laws governing the Gaussian distribution, the probability of occurrence for any chosen temperature can be derived from the extension of the plot of Figure 45. However, moderation in all things should be the watchword. Remember that the area under a Gaussian curve between ±3σ is 99.7% of the total population.

SUMMARY AND CONCLUSIONS

The temperature data derived from above and below deck storage compartments of cargo type ships are very moderate. Nowhere in any of these data was a temperature value of -65° or 160°F even remotely approached. It would seem more prudent, if a set of shipboard temperature limits must be specified, to use the Figure 45 displayed 3σ values of +38° and +88°F, or rounding these values off, 40° to 90°F.
FIGURE 1. Horseshoe Thermometer.


FIGURE 5. U.S.S. Pyro.

FIGURE 7. U.S.S. Cascade.
FIGURE 8. U.S.S. Sierra.


FIGURE 11. U.S.S. Frontier.


FIGURE 15. U.S.S. Tidewater.
FIGURE 17. U.S.S. Ajax.


FIGURE 22. U.S.S. Proteus.

FIGURE 23. U.S.S. Wright.

Figure 25. U.S.S. Peacock
FIGURE 27. Cumulative Probability of Occurrence, AE 02.
FIGURE 28. Cumulative Probability of Occurrence, AE 03.
FIGURE 32. Cumulative Probability of Occurrence, AE 3.
FIGURE 34. Cumulative Probability of Occurrence, AE 5.
FIGURE 37. Cumulative Probability of Occurrence, AE Lower Deck Composite.
FIGURE 38. Cumulative Probability of Occurrence, AE All Data Combined.
FIGURE 40. Cumulative Probability of Occurrence, AD Lower Deck Composite.
FIGURE 41. Cumulative Probability of Occurrence, AD All Data Combined.
FIGURE 42. All Ships Upper Decks Data Combined.
FIGURE 43. All Ships Lower Decks Data Combined.
FIGURE 44. All Decks/All Ships Data.
FIGURE 45. Gaussian Interpretation of All Decks/All Ships Composite.
DATA HANDLING

Temperature data from logbooks, monthly cards, and daily sheets are keypunched in formats as shown in Figure A-1 and the flow of data handling is shown in Figure A-2.

The keypunched temperature data cards are presorted per ship identification, year of the data, and deck level of the compartment or magazine from which the temperature data were taken.

The data cards are prepared as input to the TTAPE program which reads the input and writes the temperature data onto a digital magnetic tape (TTAPE Raw Data) and also prints out a set of tabulations showing the files written on this tape via the UNIVAC 1110 computer. Data from each deck level represent a file, and a sample of the tabulation is shown in Figure A-3. All manipulations and reductions of the raw temperature data are done using the tape TTAPE.

Program TTEMP is then prepared with TTAPE as input, and via the computer it sorts and counts the minimum and maximum daily temperature data into stalls of temperature data from \(-20^\circ\) to \(120^\circ\)F at a 1-degree increment. This program outputs the temperature frequency data on punched cards and tabulations as shown in Figure A-4.

The temperature frequency data cards are then checked for obvious bad data points, which are eliminated prior to the data cards being prepared as input to the CTAPE program or FCON program.

When the CTAPE program option is used, the temperature frequency card data are written on a digital magnetic tape (CTAPE Frequency Data) and a list of files of CTAPE is printed out via the computer showing what data (i.e., ship hull number, level, year of data, etc.) were written on which file of CTAPE. The CTAPE program option is used when obtaining temperature frequency data which are summed or consolidated over many levels, many ships, and many years, such that manipulation of the tape input is more efficient and flexible in the computer usage than the handling of voluminous card input.

Program CCON is then prepared for the computer run using the magnetic tape CTAPE as input to compute the consolidated temperature frequency data. The computed data are similarly punched out on cards and printed out in tabulations as the TTEMP program.
<table>
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**FIGURE A-1. Sample Input Card With Data Fields.**
The consolidated temperature frequency data cards from program CCON are then prepared as input to program TEMPF. Program TEMPF takes this input and computes the cumulative frequency and cumulative probability data of the consolidated temperature data for both separate and combined minimum and maximum temperatures. The program outputs plotted and tabulated data, as shown in Figure A-5.

FCON program option is used when the temperature frequency data cards are relatively small in volume and the consolidation of the data is limited. The program then outputs the consolidated temperature frequency data cards and a set of tabulations listing the consolidated temperature frequency data.

The output cards from program FCON are prepared as input to program TEMPF to yield cumulative frequency and cumulative probability data of the consolidated temperature data as discussed above.

All plotted data presented in this publication are augmented with tabulated data and are available in the permanent file of the NWC Ordnance Test and Evaluation Division.

DEFINITIONS OF DATA

Data presented in Figure A-4 are defined in the following:

TAPE NO. is the tape number identifying the tape that temperature data are written on.

File NO. is the file number of the tape that the data are written on.

IDENTIFICATION gives the deck level of the ship from which the data were obtained, the year of the data, the hull number of the ship, and the date of the tape.

MIN column gives the daily minimum temperature data.

MAX column gives the daily maximum temperature data.

TMIN TOTAL DATA PTS gives the total number of daily minimum temperature data available on this file.
TMAX TOTAL DATA PTS gives the total number of daily maximum temperature data available on this file.

NO. OF BAD PTS gives the number of daily minimum or maximum temperature data that were lower than -20° F or greater than 120° F.

NO. OF DATA PTS USED gives the number of daily minimum or maximum temperature data that were used in the compilation of the frequency data.

FREQUENCY OF TMIN SUB I gives the frequencies of the daily minimum temperature data from -20° to 120° F at 1-degree intervals and is denoted \( N_{t_{\text{min}}_i} \).

FREQUENCY OF TMAX SUB I gives the frequencies of the daily maximum temperature data from -20° to 120° F at 1-degree intervals and is denoted \( N_{t_{\text{max}}_i} \).

FREQUENCY OF (TMAX AND TMIN) SUB I gives the frequencies of the daily minimum and maximum, combined, temperature data from -20° to 120° F at 1-degree intervals and is denoted \( N(t_{\text{min}}_i \text{ and } t_{\text{max}}_i) \).

Data presented in Figure A-5 are defined in the following:

CUMULATIVE FREQUENCY UP TO TMIN SUB I gives the cumulative frequencies of the daily minimum temperature from -20° F up to minimum temperature of interest and is denoted \( N_{t_{\text{min}}_i} \).

\[
N_{t_{\text{min}}_i} = \sum_{j=1}^{k} N_{t_{\text{min}}_j}, \text{ where } N_{t_{\text{min}}_j} \text{ is the frequency of -20° F temperature and } N_{t_{\text{min}}_k} \text{ is the frequency of temperature of interest.}
\]

CUMULATIVE FREQUENCY UP TO TMAX SUB I is denoted \( N_{t_{\text{max}}_i} \) and is defined as follows:

\[
N_{t_{\text{max}}_i} = \sum_{j=1}^{k} N(t_{\text{min}}_i \text{ and } t_{\text{max}}_j)
\]
PROBABILITY OF Tmin SUB I is denoted \( P(t_{\text{min}_i}) \) and is defined as follows:

\[
P(t_{\text{min}_i}) = \frac{N_{t_{\text{min}_i}}}{N_{t_{\text{min}_\text{total}}}},
\]

where \( N_{t_{\text{min}_i}} \) is the total number of daily minimum temperature data used.

PROBABILITY OF Tmax SUB I is denoted \( P(t_{\text{max}_i}) \) and is defined as follows:

\[
P(t_{\text{max}_i}) = \frac{N_{t_{\text{max}_i}}}{N_{t_{\text{max}_\text{total}}}}
\]

PROBABILITY OF (Tmin AND Tmax) SUB I is denoted \( P(t_{\text{min}_i} \text{ and } t_{\text{max}_i}) \) and is defined as follows:

\[
P(t_{\text{min}_i} \text{ and } t_{\text{max}_i}) = \frac{N(t_{\text{min}_i} \text{ and } t_{\text{max}_i})}{N_{t_{\text{min}_\text{total}}} + N_{t_{\text{max}_\text{total}}}}
\]

CUMULATIVE PROBABILITY UP TO Tmin SUB I is denoted \( P_c(t_{\text{min}_i}) \) and gives the cumulative probabilities of the daily minimum temperature from \(-20^\circ F\) up to minimum temperature of interest. It is defined as follows:

\[
P_c(t_{\text{min}_i}) = \sum_{j} \frac{N_{t_{\text{min}_j}}}{N_{t_{\text{min}_\text{total}}}}
\]

CUMULATIVE PROBABILITY UP TO Tmax SUB I is denoted \( P_c(t_{\text{max}_i}) \) and is defined as follows:

\[
P_c(t_{\text{max}_i}) = \sum_{j} \frac{N_{t_{\text{max}_j}}}{N_{t_{\text{max}_\text{total}}}}
\]

49
CUMULATIVE PROBABILITY UP TO (TMIN AND TMAX) SUB I is denoted

\[ P_c(t_{\min_i} \text{ and } t_{\max_i}) = \sum_{j} \frac{N(t_{\min_i} \text{ and } t_{\max_i})}{N_{t_{\min_{total}}} + N_{t_{\max_{total}}}} \]
TAPE NO.: 7201   FILE NO.: 17   IDENTIFICATION: LEVEL 3GNOO YR 66 S WASHINGTON ON TAPE 07/24/79

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Figure A-5. (Contd.)
The various decks of a ship are numbered, using the main deck as a baseline. On all ships except aircraft carriers, the main deck is the upper most deck that runs the length of the ship; on aircraft carriers the hangar deck is the baseline. Below the main deck are the second and third decks, etc. Above the main deck are the 01 level, 02 level, etc.

Two systems of compartment numbering are presently in use, but only the newer system (begun in March 1949) is described here. Compartments are designated by a grouping of various letters and numbers, separated by hyphens. Each compartment is designated by its deck number, frame number (starting at zero at the bow and increasing towards aft), relation to ship's centerline, and usage. An example of this numbering system is 3-75-4-M. The 3 indicates the third deck; the 75 indicates that the forward boundary of the compartment is at frame 75; the 4 indicates that it is on the port of the ship (an odd number would indicate starboard side); and the M indicates that the compartment is used as a magazine. Other compartment designations are A for storage spaces, C for control spaces (areas normally manned, such as CIC communications spaces and the pilot house), E for engineering spaces, F for fuel storage, Q for miscellaneous space (shops, offices, laundry, and galley), T for vertical access trunks, and L for living (berthing) spaces.
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   AFATL/SD2 (1) Technical Library (1)

2 Air Force Cambridge Research Laboratories, Hanscom Air Force Base
   Code LKI, P. Tattleman (1)
   Technical Library (1)

1 Air Force Office of Scientific Research (Dr. J. F. Masi)
1 Air Force Rocket Propulsion Laboratory, Edwards Air Force Base (Technical Director)
1 Air Force Rocket Propulsion Laboratory, Edwards Air Force Base (RKMA, L. Meyer)
1 Air Force Rocket Propulsion Laboratory, Edwards Air Force Base (Dr. Trout)
1 Air Force Rocket Propulsion Laboratory, Edwards Air Force Base (Technical Library)

5 Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base
   AFWAL/AA (1)
   AFWAL/FI (1)
   AFWAL/FIE (1)
   Head, Research and Technology Division (1)
   Technical Library (1)

3 Environmental Technical Applications Center
   O. E. Richards (1)
   Technical Director (1)
   Technical Library (1)

1 Nellis Air Force Base (Technical Library)
2 Ogden Air Materiel Area, Hill Air Force Base
   Munitions Safety (1)
   Technical Library (1)

2 Rome Air Development Center, Griffiss Air Force Base
   Code RCRM (1)
   Technical Library (1)

1 Sacramento Air Materiel Area, McClellan Air Force Base
1 Warner Robins Air Materiel Area, Robins Air Force Base (Technical Library)
3 Armament/Munitions Requirements and Development (AMRAD) Committee (2C330, Pentagon)
2 DLA Administrative Support Center (Defense Materiel Specifications and Standards Office)
   J. Allen (1)
   D. Moses (1)
3 Department of Defense, Explosives Safety Board, Alexandria
3 Deputy Under Secretary of Defense Research and Engineering (Acquisition Policy)
   Director, Materiel Acquisition Policy (3E144), J. A. Mattino (1)
   Standardization and Support (2A318), Col. T. A. Musson (2)
2 Deputy Under Secretary of Defense Research and Engineering (Research and Advanced Technology)
   Director, Engineering Technology, G. R. Makepeace, 3D1089 (1)
   R. Thorkildsen (1)
1 Director, Defense Test & Evaluation (Deputy for Test Facilities, W. A. Richardson, 3D1043)

12 Defense Technical Information Center